MORPHOGENETICS AND PALAEOGEOGRAPHIC CONDITIONS OF ALKALI LAKES ON THE HUNGARIAN PLAIN

DR. MIHÁLY ANDÓ

A considerable number of alkali lakes and periodically waterlogged areas are to be found on the alluvial plain deposited by the rivers Danube and Tisza and their tributaries in Hungary. On the calcium-rich sediment of the Danube talus system, one finds limy, sodic, alkali lakes and alkali deposits, while on the Tisza alluvium (originating in the main from eruptions) acid solonetz and solodj types are observed. (VÁMOS R.—ANDÓ M.: 1969.)

The alkali waters and *alkali lakes form one of the characteristic types of surface waters.* As a result of the extreme climate of the Hungarian Plain, they posses characteristic hydrographic conditions. On account of their high dissolved salt content (604.5—7,124.2 mg/l), they can be classified as salt waters; the typical features are primarily richness in Na^+ and HCO_3^- ions, a high pH (7.5—10.5) and an alkaline character (MEGYERI J., 1972).

The alkali waters are extreme sites for life, populated by a particular living world different from those of other surface waters, and from those of salt waters found in other countries.

The alkali lakes on the Hungarian Plain generally formed where the morphological conditions of the surface were favourable. The beds of the lakes consist of old river-valley reaches, bends backwaters, depressions with no outlets, basins and deflation wind-furrows. *At the turn of the century* (before the regulation of the inland waters and rivers), *the alkali lakes were much more numerous and extensive than nowadays.* They are still not rare, but they are not standing waters of a uniform nature. A considerable number of them are shallow, and are in the swamp stage. These are completely covered by the aquatic vegetation. The water of another group of the *alkali waters* is already constant, and their hydrographic character is that of a lake. These latter *comprise three regional taxonomic groups on the Hungarian Plain* (Figure 1):

I. Deflation-type lakes on the sandy table-land between the rivers Danube and Tisza;
II. Polygenetic-type lakes of the Tisza valley;
III. Fresh-water erosion bed lakes of the Békés-Csanádi loess table-land.

The alkali lakes of the table-land between the rivers Danube and Tisza *mainly originated as a result of deflation,* for here the sandy material from near the surface of the talus between the Danube and the Tisza accumulated and was denuded by aeolian means (ANDÓ M., 1964; MIHÁLTZ I., 1953; MIHÁLTZ I.—FARAGÓ M., 1944—45; MIHÁLTZ I.—UNGÁR T., 1954; KRIVÁN P., 1953; MUCSI M., 1963; SÜMEGHY J., 1953). The sand and loess formations extend horizontally and can be followed for considerable distances (50—80 km); together with their

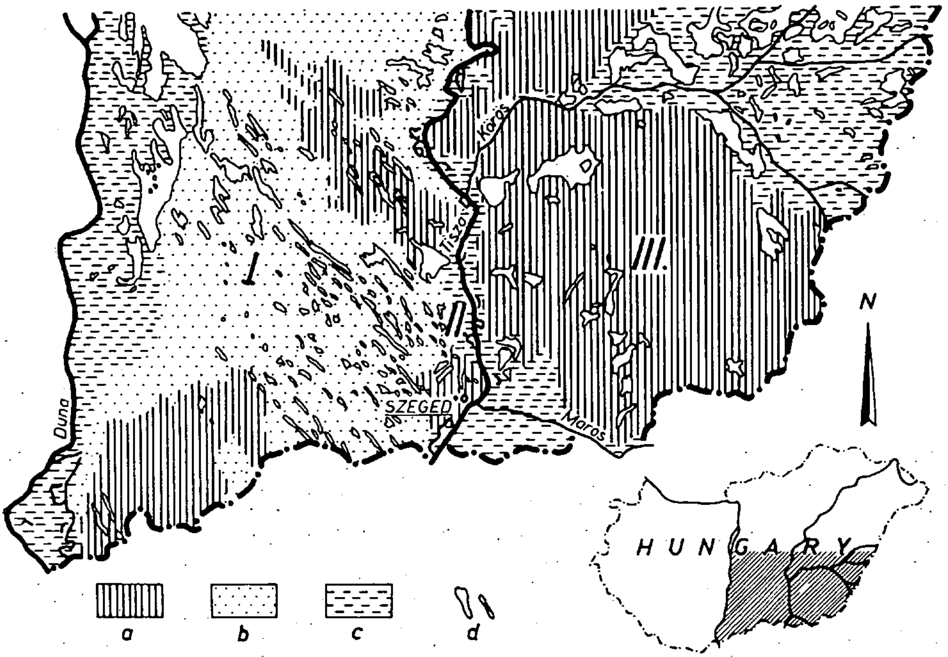

Figure 1. Surface geological picture of the lakes of the South Hungarian Plain and their environment I. The sandy table-land between the Danube and the Tisza. II. Alluvium of the Tisza valley. III. The Békés—Csanádi loess table-land. (a) loess and infusion loess formations; (b) drift-sand; c) flow-mud and meadow clay; (d) alkali depressions.

particle-distributions (coarse-grain sand and gravel, and absence of clay formations), these prove the deflation origin. This picture is particularly characteristic in the central part of the table-land, where the wind-borne origin is indicated not only by the particle form and the abrasion value, but also by the terrestrial (Ubiquista) mollusc fauna (ANDÓ M.—MUCSI M., 1967). In the course of the complex investigations it was established that the sand found here did not exhibit signs of having undergone aeolian transportation over great distance, i. e. the sand was originally transported to the area between the Danube and Tisza by flowing water. This sand was then repeatedly re-piled and transformed by the wind, and deflation depressions developed in it.

On the lower ground of the table-land, falling away to the two river valleys, the amount of sand and mud deposits of fresh-water origin increases. Large numbers of fresh-water Mollusca are found in these deposits. The sand grains here are somewhat splintery (weakly blunted at the edge) and semitransparently coloured. This structural and genetic difference appears sharply in the hydrogeographic features of the alkali lakes.

The difference in the deposit facies may be observed strongly particularly within the types of alkali waters, when in addition to the Na^+ and HCO_3^- ions determining the type, the amounts of the other chemical components (CO_3^{2-}, Cl^-, SO_4^{2-}, K^+,

Ca^{2+} and Mg^{2+}) and other hydrographic properties, such as, for example, the variation in the mass of water (permanent and periodic alkali waters), the transparency of the water, etc., may be very different in each alkali water. *In this region, therefore the varied development of the deposits during the end of the Pleistocene period and throughout the Holocene period resulted in different hydrological conditions even within the individual regional taxonomic unit.*

The accumulation of loess and the drift sands between the Danube and the Tisza can not be regarded as a continunos accumulation of sediment, since in the hotter climatic periods with higher precipitation there was also an appreciable soil formation together with a certain degree of surface denudation. Accordingly, this explains why (as a result of the denudation of the surface) the "Würm III" loess layer on the table-land sloping toward the Danube appears in patches only, while at the same time it can be found everywhere in the centrall and eastern (Tisza valley) parts of the table-land. In general, a drift-sand layer of variable thickness accumulated on the "Würm II" and "Würm III" loess layers in the Holocene period; on the action of the wind, this sand layer was shaped into dunes. On the regions between the sand dunes, however, i. e. on the regions of the lakes and periodically waterlogged ground, the deposits which accumulated largely developed from standing water.

The substratum of the Holocene formation under the lakes lying in the western part of the region between the Danube and the Tisza consists of loess from the "Würm II" period. This structure is very rich in fauna; particularly in the lower parts there is a strikingly high number (exceeding 80%) of wet-terrain (Ubiquista) molluscs, and it contains relatively few of the dry-terrain variant inhabiting groves and woods. *The "Würm II" loess layer accumulated in its staidal, initial stage. Paleocelimatologically, it is assumed that the climate at the time of the accumulation was moderately cold and not too wet,* although the quantity of cold-resistant molluscs increases compared to other groups in the central structure of the loess layer; in our view, however, the stadial maximum of the "Würm II" here did not result in a climate modification of such a nature as completely to exclude the species requiring moisture from among those enduring drought. The cover of the loess layer is in places composed of vegetable remains and humus, and with its weakly developed adobe zone can be distinguished in two parts. The thermophilic fauna present in the adobe zone confirm the climatic improvement.

The loess layer is covered by a sharply-defined layer of Pleistocene drift-sand, which accumulated in the "Würm II—III" interstadial, mild subtropical period. On the centrals and eastern parts of the table-land, this drift-sand layer is again covered by loess ("Würm III), but on the western part of the table-land this loess developed only discontinuosly. Where it does exist, it is characteristic that there is a thin inclusion of clay, varying in strata, in the upper part of the loess. Above this layer there follows a further sand deposit, which extends generally over the region between the Danube and the Tisza; this newer sandy layer is the covering stucture of this area, and in it have formed deflation depressions (lakes). It originates from the end of the Pleistocene period and the beginning of the Holocene period. *Stratographically, the separation of the Pleistocene and Holocene sand levels is possible only where the sand was deposited on a loess terrain, or perhaps where the two levels are separated from one another by sandy loess.* Where this is not the case, however, distincion between the drift-sands formed in the two different periods is very dubious. As a result of the eroding effect of the water collecting in the wind-furrogs formed on the surface of the

Early Holcene drift-sand, the wind-furrows proceeded to deepen, and in them were deposited the very characteristic formations from the Early Holocene period: lacustrian lime mud and meadow limestone.

Numerous data from test borings have provided the evidence that the substratum of the Early Hoiocene sand is fine-sandy, unassorted rock flour, with fauna of a mixed nature. As regards these latter, both thermophilic and cold-enduring types are found. Their water-requirements are variable: those of a mainly periodic aquatic nature amount to about 40%, and the other groups to 60%. On the basis of the fauna composition and the results obtained from pollen investigations, the period of accumulation of the deposit can be denoted as the fir-birch phase of the Early Holocene period.

There was also an intensive movement and accumulation of drift-sand on the Hungarian Plain in the hazel-nut phase of the Early Holocene. At that time there was a considerable transformation of the previous surface appearance. In this region, for instance, the individual lakes became deeper, but in addition a large number of new depressions too were formed. Faunistically, this period is much more difficult to follow, since the movement of the drift-sand led to the fragmentation of the skeletal remains of the molluscs and their abrasion into undeterminable forms. Where there was a possibility for their survival, e. g. deflation depressions, the microbiotope reflects a periodically wet, shady and cool microclimate, and not that generally expected regionally.

To clarify the conditions governing the development of the surface during the main phase of the Holocene period, a study was made of the potamogenous alluvial deposits of the alkali lakes and the conditions of these. In the lakes and the areas periodically covered with water, the accumulation took place of sandy mud and of mud rich in carbonate and containing unassorted detrital matter (Table 1).

TABLE 1.

Sediment-genetic processes of the lakes from the end of the Pleistocene to the present age

Period	Climate	Between Danube and Tisza (I)	Beyond Tisza (II, III)
Beech II	moderate, fairly wet (subatlantic)	drift-sand accumulation, strongly carbonate alkali sand and rock flour accumulation	intensification of alkalization, destruction of present-age accumulation woods near rivers; formation of alkali mud
Beech I	moderate wet subboreal	sand unassorted strongly carbonate rock flour accumulation, abundant vegetation, strong humification	strong soil formation, sandy mud, peaty adobe formation
Oak II	hot Atlantic	strong alkalization, slight mumous carbonate mud accumulation	running-water sand, sandy mud with rich pollen content; running-water and wild-branch type sediment variant

Period	Climate	Between Danube and Tisza (I)	Beyond Tisza (II, III)
Oak I	fairly wet Atlantic	laminated and compact fresh-water limestone formation with rich Mg content; beginning of drift-sand surface carbonate accumulation	medium-grained fresh-water sand deposit, sandy muddy clay — reaccumulated sediment formation
Hazel-nut	hot dry boreal	drift-sand accumulation, rich iron accumulation in upper part of sand intense alkalization	accumulation of gravelly coarse-sand of runn ng-water origin with formation of floodplain swamp sediment
pine-birch	cold wet preboreal	drift-sand periodic-water lacustrian deposited unassorted rock flour	erosionperiod, river valley cutting, loess surface crumbling, running-water coarse-grain sediment formation
Yonnger tungra	cold dry $Drias_2$	drift-sand accumulation, strongly loessy fine sand formation	loess, sandy locss, clayey mud accumulation
Middle tundra	subarctic Allerőd	drift-sand	clayey mud, sand formation
Older tundra	$Drias_1$	loess, sandy loess	loess, running-water sandy mud, clay formation
Würm III	cold dry	loess formation	infusion loess and clay formation

The carbonate became concentrated as a result of the fact that the calcium-containing material in the higher terrain adjacent to the deflation depressions was dissolved up by the precipitated rain-water and was transported towards lower areas. The sodic water accumulated in the depressions precipitated out the lime from the evaporating solution in the form of minute particles, and this sediment provides the characteristic lime mud of the alkali waters. If the precipitation of the lime took place in the presence of sand grains, then the fine mud was deposited onto these sand grains, and in this way lime-mud sand was formed. At times the carbonate precipitation does not occur in the form of independent grains; instead, the sand particles are cemented together by the solid carbonate, and then limy sandstone beds are formed. In many places, however, the precipitation of the lime is so intensive that sand in it is insignificant in comparison, and meadow limestone is then formed. On the western slopes of the table-land between the Danube and the Tisza a carbonate-rich, small-frain, sandy mud was deposited with a loose colloidal structure, containing a considerable concentration of soda. This is also the form of the carbonate mud in the alkali lakes found in the central part of the table-land.

In contrast, the alkali accumulation is very different in the sand depressions faling away to the Tisza valley (Figure 2).

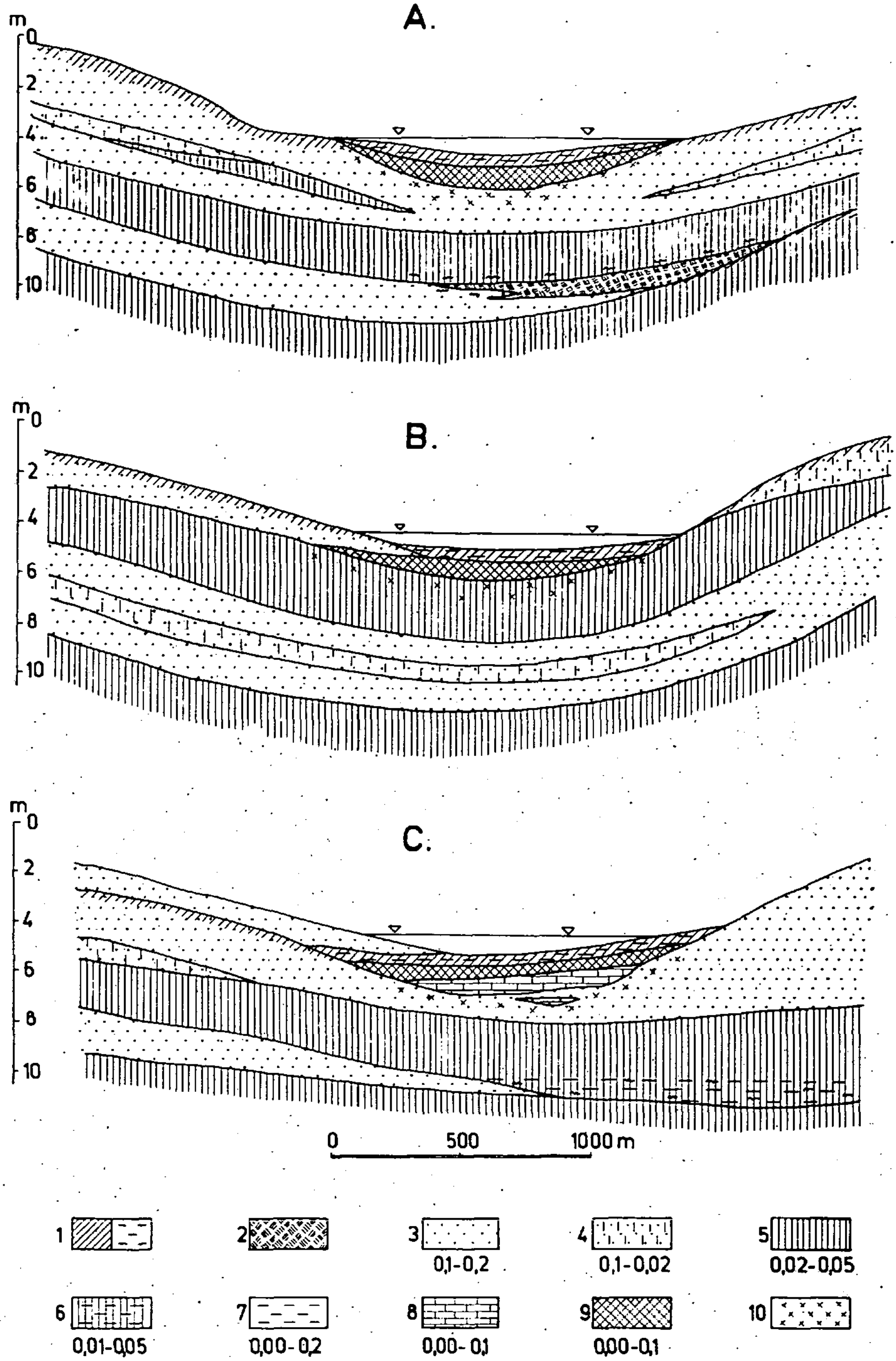

Figure 2. General geological profile of the lake types between the Danube and the Tisza

A. Lakes of the sandy table-land sloping down to the Danube valley. B. Lakes of the central part of the sandy table-land. C. Lakes of the sandy surface sloping down to the Tisza valley.

1. sediment rich in humus with plant residues;
2. peat; 3. drift-sand; 4. loessy fine sand;
5. loess; 6. muddy loess; 6. lime-muddy sand;
8. meadow limestone; 9. carbonate mud; 10. carbonate-rich sand, loess.

As in the western part of the table-land, here too the lacustrian carbonate deposited on drift-sand. *Limy sand was first deposited in intermittent patches (then higher in a coherent layer) on the uneven surface of the Pleistocene, while this was followed above by the formation of sandy limestone.* The thickness of the limestone layer varies from region to region (in general 30—70 cm), and its internal structure is not homogeneous. The lowest layer consists of loose sand grains, the central part is more compact, while the upper part contains sharply distinguished fine strata, and has a strongly porous structure. Above the limestone there follows a white, or greyish-white, loose, easily crumbled layer of the carbonate mud, and above this humous, rock-flour sand in a sharply distinct layer of variable thickness (20—50 cm). In places in this humous formation traces of peat can also be detected, pointing to a climate with more precipitation than the present one. The cross section of the Holocene accumulation was also outlined by the characterized layersequence. It was found that *a significant surface deposit on the Hungarian Plain was formed in the Holocene period only on the overflow regions of running waters and on the regions of the surface depressions (lakes).*

The rate of accumulation and the palaeoclimatic conditions are very well indicated by the limnetic deposits in the lakes of the sandy table-land between the Danube and the Tisza. The pictures of the pollen and the fauna in the individual lacustrian deposits give a good reflection of the palaegeographic situation. In the lakes in question (between the Danube and the Tisza) pollen pitures and fauna favouring a cold climate are found only in a few species and in low individual numbers in the sublayered drift-sand (Galba truncatula, Pinus silvestris). Accordingly, it is also considered possible that *the drift-sand comprising the base of the carbonate deposit may have been formed in the post-glacial pine-birch period at the end of the Pleistocene.* In the lower part of the sandy limestone structure the species enduring periodic drought predominate, and the proportion of those requiring constant water is significantly decreased (ANDÓ M.—MUCSI M., 1967). The coenosis too points to periodic wetness and a terrestrial wet terrain. On proceeding upwards in the series of fresh-water limestone layers, however, the number of individuals increases rapidly. The maximum number of individuals is found at the boundary of the lower and central layers.

The permanent and periodic aquatic, eurytherm species predominate in the composition of the fauna, but the number of those tolerating cold also increases. This population suggests that the climate on this area was wet, and colder than the preceding one. This is also confirmed by the pollen picture, for the thermophilic deciduous species (Quercus, Tilia, Ulmus, Juglans, a few Faugs) in the sandy lower level of the limestone indicate a hot, rainy climate, while the Petula, Salix and Pinus in the central, more compact limestone layers point to a temperature decrease. Both cold-resistant (eurytherm) and themophilic species occur therefore in the central, compact limestone bed. It is here that the proportion of permanent and periodic aquatic fauna is the highest. The species satisfied with periodic water occur in the greatest quantities, while the ratio of the water-side to the dry-land species favouring moisture is shifted in favour of the water-side species (ANDÓ M.—MUCSI M., 1967). The above data permit the conclusions that the climate was a wet one, that there was rich water-side vegetation in this area, and that the lakes had permanent open water surfaces.

In the thin-laminated structure of the uppermost fresh-water limestone the numbers of those species requiring permanent water is decreased, whereas the proportion of those satisfied with periodic water is unchanged. The proportion of the water-side

Succinea oblonga in the deposit is increased considerably; this means the recession of the permanent water-surface, but complete drying-out is excluded by the high number of individuals. The pollen picture indicates that the thermophilic deciduous trees again gain ground, implying a newer increase of temperature, accompanied by a certain drying-up.

In the lower part of the carbonate mud above the fresh-water limestone a decrease in the number of individuals is observed, the conditions leading to an increase in the proportion of the fauna requiring water and having wide limits of endurability (Anisus spirorbis, Succinea oblonga). In contrast, in the upper part of the carbonate mud the dry-land, thermophilic species not demanding moisture predominate over the periodic and water-side species. This stage means the enhancement of the dryness and the further increase in temperature of the climate.

Again, carbonate determinations show that the carbonate content of the underlying drift-sand is somewhat higher than that of the surface drift-sand. This is probably due to the fact that the carbonate content of the upper layer was washed out by the action of the precipitated rainfall and accumulated in the lower layers. *The carbonate content of the lacustrian deposit is considerable in the lower part of the fresh-water limestone, but low at the lower boundary of the central layer.* This decrease can generally be correlated with the local insufflation of sand, which is also proved by the lamination of the deposit. *A further increase of carbonate can be observed in the other parts of the fresh-water limestone.* The maximum is found in the lower part of the carbonate mud situated above the limestone (87%). In the structure above this layer there is at first a slow, and then a more rapid decrease in the carbonate content, so that in the upper humous layer it is only 25%.

In contrast with the deflation depressions in the aeolian deposits between the Danube and the Tisza, *the lakes in the south-east of the area beyond the Tisza (Békés—Csanádi table-land, III) are found in fresh-water erosion depressions.* As a consequence of the intensive fresh-water accumulation work, these lakes are very few in number. The considerable subsidence of this region in the Pleistocene period is compensated for by a fresh-water deposit serveral hundred metres thick. At the end of the Pleistocene the tempo of the subsidence decreased, and as a result not only the fresh-water alluvium, but also a falling-dust formation was deposited on the area in the final glaciation period (ANDÓ M., 1964; MOLNÁR B., 1966). However, the falling-dust loess formation became mixed in with the fresh-water accumulation, and accordingly several facies variants (sandy loess, clay loess) resulted in this region. A typically dry-terrain aeolian formation is not found in the region, for the falling dust either accumulated on a wet terrain, or was so transformed in structure on the action of the soil-water that it completely lost its typical loess character. *Here an infusion loess developed, and the present-day alkali lakes are also descending into this. In the infusion loess layer one finds calcium carbonate-rich clayey abobe zones, frequently washed together by the action of the soil-water and the standing-water cover of the region.* These layers have a considerable effect on the present hydrographic conditions of the lakes.

As a consequence of the flowing-water erosion work observed in the lakes, the alluviation of the river beds in the Pleistocene period was followed by an only partial similar process in the Holocene period. For this reason, the residual valleys of the old marshes and river beds are today's alkali standing-water depressions. *The alluviation of the lakes with infusion loess matter in the Holocene period occurred to a considerable* *extent, and thus only a small number of lake beds can be observed.* Where the extent of the silting-up is above the present average soil-water level the water cover of the surface is only periodic, but where it is below the present level the water cover is permanent. The lakes containing periodic water are of a very strongly alkaline character, while the lakes with permanent water are less so.

The deepest-lying formation (25—50 m depths) investigated by us is mud-clay from the Pleistocene period. On the basis of the layer sequence, it is probable that this is a Riss-Glacial formation. Its thickness and the extent of its area are variable, while from below upwards it is composed of ever finer particles. Gravelly, coarse-sand formations (Riss—Würm interglacial) were deposited on this structure, indicating a new rhythm in the deposition. This rhythm also consists of deposits which are increasingly fine in the upwards direction, the final uppermost member being a Würm falling-dust formation which marks the end of the Pleistocene. The surface formation of the Békés—Csanádi loess table-land, consisting predominantly of infusion loess material, is formed by this layer.

The Holocene represents a new rhythm in the surface development. Based on the particle composition of the transported alluvial deposit, the working capacity of the flowing waters in this rhythm were weaker than the earlier ones, and in direct relation to this the erosion activity was also less pronounced. The deposition of the fresh-waters sediment became periodic, as indicated by the fine sandy mud, and by the clay and clayey mud deposited in the standing water. The substratum of the Holocene deposit is formed by the "Würm III" infusion loess, but much more general than this is clay from the Pleistocene period. The thickness of the clay is 4—10 m, and in practice it can be regarded as impermeable. Above it, in the line of the ancient river valleys, coarse-grained sand accumulated (in a number of places gravelly coarse sand). In more rainy years there is a rapid soil-water movement in the river-valley zones filled with this porous deposit, and under the layer pressure in the lower-lying terrain the soil-water may even well up. In the upwards direction the particle composition of the coarse grained sand becomes increasingly finer, and the final layer is always a strongly unassorted sediment of varied development. It is well known that the ox-bow lake state in the alluviation of the old river beds began at the beginning of the late Holocene and is still continuing today. The beds (lakes) were mainly filled in with infusion loess washed in from their environment, and have become strongly alkaline as a consequence of the environmental climate and the hydrograpic features. On the basis of the layer sequence of the alluviation rhythm in the Holocene period, a clear distinction can be made between the fresh-water deposits of coarse and medium-grained sand (early Holocene) and the always unassorted clayey mud (late Holocene) layer composition accumulating with standing and periodic water.

In the genesis of the lakes found on the direct Tisza alluvium (II) the main mechanism which can be observed is a fresh-water one. In the Holocene this terrain underwent not only intensive subsidence, but also considerable erosion. Here, surface erosion and accumulation took place to a depth of 15—20 m. The sedimentation of the covering layer can be regarded geographically as the only accumulation phase, where the granule size of the deposit becomes gradually finer in the upwards direction. At the lowest level is the loose fresh-water sediment, followed by a layer of muddy sand, clayey mud, and finally meadow clay. Since the control of the flood waters and the internal waters, this latter layer has been undergoing a process of considerable alkalization.

On natural or anthropogenic effects, all of the present standing waters of the Tisza valley are enclosed channel fragments. The water of the majority of them is not alkaline, since on flooding the water reserves of the lake are exchanged from the river Tisza. These water surfaces are subject to appreciable human intervention (storage lakes, fisch lakes). Those ox-bow lakes which are already strongly silted up are not very suitable for irrigation purposes, because of the chemical composition of their water and the high centration of salts. They are mainly utilized as inland stor age lakes, and as a result of their favourable natural features they are nature conservation areas.

To summarize; With regard to the historical aspects of the palaeogeographic development of the lakes on the Hungarian Plain, it can be stated that from the end of the "Würm III" a periodic water cover was involved in the case of certain lakes. In the hazel-nut phase of the early Holocene there was an intense movement and reaccumulation of drift-sand. In our view the channel bed of the standing water is a result of the intensive surface change in the hazel-nut phase at the end of the "Würm III" and in the early Holocene. Thus, the individual depressions have been covered by water not only from the oak phase of the early Holocene, but from the end of the "Würm III" period. In the drier hazel- nut phase there was a significant decrease of the water area and a shift of the surface, but on the Hungarian Plain this did not mean the complete cessation of the lacustrian state.

In the case of the lakes in the hazel-nut phase, generally horizontal shifts of the shores took place, with variations of form of the shores in the directions NW-W and S-SE-E. This phenomenon must also be reckoned with in the oak phase, with the difference that there were then significant layer deficiencies as a result of their lacustrian abrasion. It is probable that the extension of the lakes attained its maximum at this time, for in the beech I and beech II phases of the Holocene period the water area further decreased. At the same time, in contrast with this, the water cover of the depressions became constant because of the impermeablle effect of the earlier accumulated carbonate mud.

References

Andó M. (1961—64): Geomorphologische und Hydrographische Charakterisierung des Kunfehér-Sees und Seiner Umgebung. Acta Geographica Szegediensis, Tom. V, Fasc. 1—7.

Andó M. (1966): Mikroklimaverhältnisse der sodahaltigen Teiche in Südlichen Teil der Grossen Tiefebene. Acta Geogr. Szegediensis, Tom VI, Fasc. 1—4.

Andó M.—Mucsi M. (1967): Widerspiegelung der jungpleistoränen und holozänen Klimarhytmen in den ablagerung sverhältnissen der sodahaltigen Teiche und periodischen Wasserdeckungen im Donau—Theiss-zwischenstromland. Acta Geographica Szegediensis, Tom. VII, Fasc. 1—6.

Kriván P. (1953): A pleisztocén földtörténeti ritmusai. Az új szintézis. (Geological rhythms of the Pleistocene. The new synthesis.) Alföldi Congress.

Megyeri J. (1959): Az alföldi szikes vizek összehasonlító hidrobiológiai vizsgálata (Comparative hydrobiological study of the alkali waters on the Hungarian Plain.) Annual of the Teachers' Training College, Szeged.

Mihâltz J. (1953): Az Alföld negyedkori üledékeinek tagolódása. (Distribution of the Quaternary deposits on the Hungarian Plain.) Alföldi Congress.

Mihâltz I.—Faragó M. (1944—45): A Duna—Tisza közi édesvízi mészkőképződmények. (Fresh-water limestone formations in the region between the Danube and the Tisza.) Annual of the Alföldi Scientific Institute.

Molnár B.—Mucsi M. (1966): A Kardoskúti Fehértó vízföldtani viszonyai. (The hydrogeological conditions of the Kardoskúti Fehértó.) Hidrológiai Közlöny, No. 9, Budapest.

Mucsi M. (1963): Finomrétegtani vizsgálatok a kiskunsági édesvízi karbonátképződményekben. (Finestratigraphical studies on the fresh-water carbonate formations of Kiskunság.) Földtani Közlöny, 93, Budapest.

Sümeghy J. (1953): A Duna—Tisza közének földtani változata. (Geological variant of the region between the Danube and the Tisza.) Annual Reports of the National Geological Institute, Budapest, from 1950.

Treitz P. (1930): A Duna—Tisza közi belvizek és hasznosításuk. (The inland waters of the region between the Danube and the Tisza, and their utilization. Hidrológiai Közlöny, 10, |Budapest.

Vámos R.—Andó M. 1969: The hidrobiological climatic and pedological factors in the alkalization of soils of the Great Hungarian Plain. Acta Geographica Szegediensis, Tom. IX. Fasc. 1—3.

Mihâltz I.—Ungár T, (1954): Unterscheidung zwischen dem fluviatilen und vom windtransportierende Sand. Földtani Közlöny 1—2. Budapest, 1954.

Megyeri I. (1972): Übersicht über die Forschungen der Ungarischen Natrongewässer. Suppl. Szeged, Ped. Univers. 1972.